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Grouping, semantic relation and imagery effects in individuals with Down syndrome

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Abstract

Down syndrome (DS) is associated with a specific verbal short-term memory (STM) deficit. This study explored the effects of grouping, semantic relations and visual presentation upon verbal STM recall performance in a group of 15 individuals with DS and 15 vocabulary-matched typically developing (TD) children. Participants were presented with memoranda in either a temporally grouped schedule, such that items were grouped as pairs, or in an equally spaced presentation schedule. The two items constituting each pair were either semantically related or unrelated. Performance across these conditions was compared in verbal or verbal plus visual presentation modes. Significant memory recall benefits were observed across populations as a result of temporal grouping, semantic relations and verbal and visual combined presentation. However, a reduced benefit of semantic relation in the DS group compared to the TD group indicated that those with DS were less influenced by LTM relational knowledge. In addition, those with DS only experienced a grouping benefit during verbal and visual combined presentation, in contrast to the TD group who experienced grouping benefits throughout. This indicates that individuals with DS are poorer at encoding temporal context for purely verbal memoranda. These findings were replicated in a follow-up experiment, aimed at aligning baseline performance in the two populations. This study provides encouraging evidence that, despite their difficulties in some areas, individuals with DS can benefit from the use of grouping and LTM knowledge to assist their verbal STM performance under certain circumstances.

Grouping, semantic relation and imagery effects in individuals with Down syndrome

Verbal short-term memory (STM) is responsible for the short-term storage and maintenance of verbal input such as words and digits. Associations between individuals' verbal STM performance and the development of vocabulary acquisition, comprehension and syntax are well established (Baddeley, Gathercole, & Papagno, 1998; Baddeley, Papagno, & Vallar, 1988; Ellis & Sinclair, 1996; Vallar & Baddeley, 1984). In turn, this has driven research seeking training routes to enhance memory performance. Recent memory training programs have primarily aimed at improving the broader concept of working memory, e.g., CogMed (www.cogmed.com), that is, individuals' ability to store and simultaneously process information, be it verbal or visual. The relevance of such work follows from the fact that working memory is implicated in various wider abilities such as mathematics and reading ability (Gathercole, Pickering, Knight, & Stegmann, 2004; Leather & Henry, 1994). Nevertheless, given the role of verbal STM in driving aspects of language development, understanding how one might improve verbal STM performance specifically is also extremely relevant for populations known to experience particular problems in the language domain.

One population among whom verbal STM tends to be specifically poor is those with Down syndrome (DS). Individuals with DS experience varying degrees of general learning difficulties. Nonetheless, verbal STM is a domain in which, as a group, specific difficulty is consistently displayed, with performance on verbal STM tasks being significantly poorer to that observed in comparable visual STM tasks, as well as significantly poorer than the performance of matched control groups, be they typically developing, or individuals with other learning difficulties (Brock & Jarrold, 2005; Hulme & Mackenzie, 1992; Jarrold &

Baddeley, 1997; Jarrold, Baddeley, & Hewes, 2000; Jarrold, Cowan, Hewes, & Riby, 2004; Laws & Bishop, 2003; Vicari, Marotta, & Carlesimo, 2004).

Verbal STM has a limited capacity (Cowan, 2001; Miller, 1956), according to Cowan (2010) this capacity is limited to around 3-5 chunks in typical adults. However, the amount individuals are able to recall during STM tasks can also vary according to other factors regarding the given recall circumstances, one being the structure or organisation of the items presented for recall. For example, it has long been known that presenting memoranda with grouping imposed on the items using perceptual separation, such as by separating items by temporal pauses, results in benefits to recall in typically developing groups. Such perceptual grouping effects are observed in both adults (Bower & Winzenz, 1969; Frankish, 1995; Maybery, Parmentier, & Jones, 2002; Melkman, Tversky, & Baratz, 1981; Ryan, 1969), and children (Harris & Burke, 1972), including pre-schoolers (Calfee, 1969). It has been suggested by Farrell (2012) that clusters (or groups) provide a hierarchical temporal context; recalling the context consequently helps an individual to recall the items within that group context. In this sense, grouping divides the verbal sequence into separate sub-sequences, such that individuals can process coarse temporal context for each cluster and a finer temporal context for the items constituting each cluster. Such a hierarchical structure allows for organised encoding and retrieval of items. This notion is also compatible with working memory models such as Burgess and Hitch's (1992) connectionist model, which invokes the concept of a context timing signal (see also Burgess, 1995). In Burgess' (1995) model the 'context' is defined using the metaphor of a moving window, with item nodes forming temporary associations with other items nodes in that same window (shared context). Hence, temporally grouping items at presentation may lead to enhancements in performance, as discussed above, as a result of structured, hierarchically organised encoding and recall of items.

Grouping may be a useful strategy for individuals with DS to adopt given that they experience verbal STM difficulties and appear to have a reduced verbal STM capacity (Purser & Jarrold, 2005). One possibility is that a lack of strategic grouping may be a contributing factor to the consistent finding of poor verbal STM performance in this population. Spontaneous grouping tendencies for memoranda (that are not readily grouped at presentation), do not appear to develop in typically developing children until they reach around 8 or 9 years of age (Towse, Hitch, & Skeates, 1999). It is possible that similarly, without instruction, individuals with DS may not develop spontaneous grouping strategies for unstructured verbal input, given their mental age. Thus, for young children (and possibly individuals with DS) who would otherwise struggle to spontaneously group verbal memoranda it may be particularly useful to provide grouped structure at input. As such, temporally structured presentation of input may induce organised encoding and recall. Previous studies have attempted to actively train individuals with DS to enhance their organisational memory strategies, observing subsequent benefits (Broadley & MacDonald, 1993; Broadley, MacDonald, & Buckley, 1994), with skills maintained at a later date, but appearing to be gains only on the specifically trained tasks. While individuals with DS therefore appear to benefit from organisational instructions, to our awareness, no existing studies have explored the nature of possible grouping benefits in individuals with DS simply by presenting memoranda in a format that can be readily organised into perceptual groups.

The first aim of the current study was therefore to explore whether individuals with DS benefit from grouped presentation of memoranda. This was done by measuring recall performance for lists of items presented at a temporally grouped rate, such that pairs (groups) were presented with the temporal interval between each pair being longer than the interval occurring between the two items constituting the pair. Recall for such stimuli was compared to that for items presented within a non-temporally grouped (equal) schedule. A benefit of

grouped presentation would indicate that individuals with DS spontaneously make use of the pre-grouped format of the memoranda, storing and retrieving the items in memory according to the temporally grouped organisation. If recall performance is enhanced for those with DS, then this would have implications for the presentation of materials in educational settings.

The effect of temporal grouping upon those with DS was therefore compared to that seen in a typically developing (TD) matched control group of children. If individuals' encoding and recall potential reflects a developmental progression, then one might expect that individuals with DS will benefit from temporal grouping to a similar degree to that of a vocabulary matched control group of TD children. However, given the specific verbal STM problems experienced by those with DS, whereby they tend to perform poorer on tests of verbal serial recall than matched controls, it may be that the temporally grouped presentation does not enhance recall for those with DS to the extent expected for their mental age. For example, the specific verbal STM deficit observed in those with DS may be due to differential processing of the verbal input, such that temporal structure is processed or encoded in a way that is not equivalent to their TD peers.

Another factor that supports verbal STM span performance in TD groups is the top-down influence of existing knowledge of the memoranda held in long-term memory (LTM). For instance, in immediate serial recall tasks concrete words are recalled better than abstract words (Paivio, Clark, & Khan, 1988), and high frequency words better than low frequency words (Roodenrys, Hulme, Lethbridge, Hinton, & Nimmo, 2002). Typically, individuals are able to remember more items during STM tasks when the items are meaningful (Caza & Belleville, 1999; Graf & Schacter, 1989; Poirier, Dhir, Saint-Aubin, Tehan, & Hampton, 2011). For instance, the 3 letters 'U, S, A' are more memorable than the 3 letters 'B, J, T' (Bower, 1972), due to the meaning associated with the letters in the former list. Meaning (e.g., for the 3 letters FBI), allows for multiple items to be encoded as one whole unit, or

chunk. Accordingly, Cowan et al., (2010) report that it is both the size of the chunks as well as the number of chunks stored and recalled that increases across development, resulting in improvements in memory performance. Thus, one key strategy that individuals can use to increase memory span is to store verbal input in semantically organised chunks. Items constituting a semantic chunk will therefore have associations with one another, in a similar vein, some researchers also argue that effects such as frequency are, at least partially, due to item associative benefits (Stuart & Hulme, 2000), whereby items that co-occur more commonly develop associations with each other, thereby enhancing recall for these items. When items have semantic inter-associations they should therefore be easier to recall, whereby remembering one item then cues participants to also recall the associated item, perhaps with sets of related items constituting separate semantically organised chunks.

Thus, a second manipulation in this study was of the semantic relatedness of items. Specifically, items were presented in either a semantically related arrangement, such that two consecutive items were related, compared to when these same items were presented in a non-related arrangement (See Figure 1). Each pair was first chosen on the basis of subjective judgements of relatedness; the two items in any given semantically related pair were considered by the experimenter to be clearly related, such as dog and bone, umbrella and rain, boat and sea. However, to provide an additional objective measure, latent semantic analysis was then used to confirm the degree of semantic relation for each of the chosen pairs of items, as further outlined below. Although selective verbal STM problems are observed in DS, Jarrold, Baddeley, and Philips (2007) found that a group of individuals with DS showed no specific verbal LTM deficit. Additionally, previous research indicates that those with DS are influenced by top-down processes such as word knowledge during STM recall. For instance, Brock and Jarrold, (2004) found a significant lexicality effect in those with DS. This indicates that individuals with DS may also have the potential to benefit from semantic

association manipulations during verbal STM tasks. Nash and Snowling (2008) found evidence that during a semantic fluency task the number of items in each semantic cluster was not decreased in their DS group compared to a matched TD group. However, individuals with DS did recall fewer clusters than the TD group. Nash and Snowling concluded that semantic organisation is not impaired in DS; however they suggest that their findings most likely reflect the presence of compromised retrieval strategies, such that the DS individuals are poorer at moving between clusters. Previous research therefore indicates that verbal LTM is organised similarly in those with DS and does influence STM performance, perhaps somewhat automatically, e.g., as shown by strong lexicality effects (Brock & Jarrold, 2004). However, strategic, organised retrieval based on semantic associations may be less efficient in those with DS compared to a TD comparison group (Nash & Snowling, 2008).

In the current study, for all trials, the memoranda were words presented auditorily. Auditory presentation was used in order to gain a relatively pure measure of verbal STM. However, it remains possible that individuals with DS rely on visual maintenance strategies to compensate for their difficulties in verbal STM tasks. For instance, rather than using existing verbal associations when presented with semantically related items, individuals might imagine the two items comprising a related pair in a single image. This type of interactive imagery was explored by Bower (1970). Bower found that when individuals were instructed to imagine two items interacting, they subsequently had better memory recall for these items, compared to when they used other strategies such as verbal rehearsal. In the current study, the addition of a picture for each item in the pair at presentation would be expected to encourage visual processing/visual strategies during maintenance and recall. If individuals experience larger benefits of semantic relation, or of grouping, during the stage when pictures are presented simultaneous to the verbal item (verbal plus visual presentation condition), then this would be an indicator that they are benefiting from a visual process, such

as interactive imagery, or a visual grouping mechanism. The inclusion of a verbal plus visual presentation condition therefore had the potential to highlight key differences in strategy use in those with and without DS, which should increase our understanding of the verbal STM difficulties observed in this population.

Thus, to gain an understanding of the nature of potential grouping and semantic relation benefits, a visual presentation condition was also included whereby each relation x grouping block (see Figure 1) was presented with a visual picture, in addition to the auditory label. The verbal only presentation condition was always carried out first to avoid encouraging participants' use of imagery in the initial verbal only stage. As a result, participants may be expected to have slightly better overall performance in the visual stage.

To summarize, this study set out to test whether individuals with DS as well as matched TD individuals, experienced grouping benefits, encoding/recalling input according to the structured temporal context. Recall of items presented in a temporally grouped schedule, was thus compared to recall of these same items when presented at an equal pace. Second, this study explored whether those with DS, compared to those without, found it easier to recall items based on associations/semantically organised chunks, by recording participants' recall of items that were presented in a semantically related arrangement, compared to when the same items were presented in a non-semantically related arrangement. This second manipulation was crossed with the first resulting in four temporal grouping x semantic relation blocks. Finally, performance across these blocks was compared when memoranda were presented verbally and when presented with a picture accompanying the verbal label. It was hypothesised that while the TD group would display better performance with the addition of visual presentation, those with DS may experience a larger benefit, since visual STM performance is comparably superior to verbal STM in individuals with DS. If the DS group do not experience the same benefits as the TD group as a result of the above

manipulations, this may highlight areas that contribute to poorer verbal STM performance in those with DS, such as differential encoding of temporal structure, or poorer context based retrieval strategies, as well as possibly poorer strategic use of the semantic organisation of the input, or less activation of semantic relations in LTM.

In the current study, the aim was to explore whether individuals were better at recalling each unit (pair), as a result of grouping/relation. Parmentier, Andres, Elford, and Jones (2006) reported that for temporally grouped input, more within group item migration errors occurred, but with improvements in recall of items overall, in the correct group. Each pair may constitute a separate group or unit, as a result of grouping the two items, and/or due to associating two semantically related items in a given pair, potentially as semantically organised chunks. Given this, we scored items according to correct pair position, e.g. item '1' and item '2' of pair 'a' could be recalled correctly in either of the serial positions '1' or '2' of pair 'a'; rather than strict serial recall (e.g., whereby item '1' can only be recalled correctly in position '1' of pair 'a'). Thus, we allowed for the order of the two items of a given pair to be interchangeable.

Experiment 1

Method

Design

This study used a 2 x 2 x 2 x 2 mixed design, the within subjects variable of semantic relation had two levels: related pairs and unrelated pairs, the within subjects variable of temporal grouping had two levels: ungrouped and grouped, the within subjects variable of presentation mode also had two levels: verbal only vs. verbal and visual combined. The between subjects variable of population had two levels, DS and TD. As discussed above, the dependent variable was the number of items recalled in correct pair position, thus unlike strict serial recall, we additionally allowed for the items within a given pair to be interchangeable,

i.e., the items in the following list: ‘dog, cat, boat, sea, chair, table’, could also be correctly recalled with the two items in one/each of the pairs in reverse order, such as ‘cat, dog, sea, boat, table, chair’. All references of ‘memory recall’ regarding the current study in the remainder of the paper, thus refer to items recalled in the correct pair position.

Participants

Fifteen individuals with Down syndrome (mean age = 20 years (y), 5 months (m), $SD = 7y, 6m$, range: 10y, 5m -29y, 11m), and 15 typically developing (TD) children (mean age: 6y, 8m, $SD: 1y, 7m$, range: 4y, 11m -9y, 8m), took part in this study. The children were matched individually to those in the DS group for vocabulary using the British Picture Vocabulary Scale (BPVS II), (Dunn, Dunn, Whetton, & Burley, 1997); there was no significant difference between the two groups’ verbal mental age scores, (DS: $M = 95.87$ months, $SD = 24.56$; TD: $M = 95.53$ months, $SD = 17.32$; $t = -0.05$, $p = .96$). Participants with Down syndrome were recruited from local Down syndrome support groups in the Bristol area and contacts from previous studies. Participants required comprehension abilities to understand simple task instructions, as well as the ability to verbalise responses. Any participants that did not meet these requirements, based on the experimenter’s judgement, were not assessed. The typically developing control children were recruited from a local primary school; all children who obtained parental consent were included in the study.

Procedure

The task was carried out on a laptop computer (Screen size: 22.9 x 38.1cm) and was created using Revolution Studio 2 software. Participants were presented with instructions on the computer and the experimenter read these instructions aloud. Each participant completed a practice trial consisting of 6 unrelated items presented at an equal pace of one per second,

participants were provided with additional practice sessions prior to starting the experimental trials where necessary. The verbal only presentation condition was completed first, in which all items were presented auditorily. A cartoon character was displayed in the centre of the screen during the presentation of auditory items. In each trial 6 items were presented consecutively, a speech bubble popped up next to the cartoon character in synchronisation with the auditory presentation of each item. In the two ungrouped blocks each item was presented for 900ms, with a 600ms interval between each item. In the two grouped blocks items were presented again for 900ms, the interval between the two items constituting a pair was 100ms, while the interval between each pair was 1100ms. Thus, the overall duration of each trial in the ungrouped compared to the grouped blocks was equivalent. There were therefore four blocks in the verbal only presentation condition, presented in following order for both presentation conditions: 1. Non-related & Ungrouped arrangement, 2. Related Ungrouped arrangement, 3. Non-related & Grouped arrangement, and 4. Related & Grouped arrangement (See Figure 1). Each block consisted of 5 trials. The four blocks were subsequently re-presented in the verbal and visual combined condition, whereby each item was presented in auditory format along with the corresponding picture being simultaneously shown in the centre of the screen. The SVLO picture set was used to obtain simple coloured item images (Rossion & Pourtois, 2004). In each presentation condition the two temporally grouped blocks appeared after the two non-grouped blocks; this was to avoid participants' spontaneous use of grouping during the non-grouped presentation format. In both the verbal only presentation condition and the verbal and visual presentation condition, the items in each trial in each block were presented as shown in Figure 1.

All pairs of items were inputted into a latent semantic analysis (LSA), (Deerwester, Dumais, Furnas, Landauer, & Harshman, 1990), a statistical method that extracts semantic relations among terms. As explained in an overview by Dumais (2007), LSA does this by

analysing the contexts of use of the terms/words in documents, passages, or sentences. From a large collection of texts, a term-document matrix is generated, which shows similarity structures. Similarity in this sense then is determined by the degree to which words are used in similar contexts. We used an online tool for analysis provided by the University of Colorado on their LSA page: <http://lsa.colorado.edu>. The chosen topic space for this analysis was general reading up to 1st year of college, i.e., a large collection of texts coming under this category were analysed. Similarity scores were computed between -1 and 1 for all inputted item-item combinations. An unrelated t-test was then carried out on the two sets of ratings (1. Ratings for the unrelated arrangement of pairs and 2. Ratings for the related arrangement of these same pairs). The related pairs ($M = .39$, $SD = .20$), resulted in significantly higher LSA ratings than the unrelated pairs ($M = .10$, $SD = .09$), ($t = -7.40$, $p < .001$).

Results

A 2 x 2 x 2 x 2 Anova was carried out to explore the effect of the two levels of temporal grouping (Ungrouped vs Grouped presentation pace), the two levels of semantic relation (Non-related vs Related presentation arrangement) and the two levels of presentation format (verbal only vs verbal and visual presentation condition), upon recall performance in the two populations (DS and TD). Corresponding descriptive statistics are shown in Table 1.

There was a significant between subjects effect of population, $F(1, 28) = 22.72$, $p < .01$, $\eta^2 = .45$, with the DS group displaying reliably poorer performance than the TD group.

There were significant recall benefits as a result of presenting items at a temporally grouped pace, $F(1, 28) = 13.36$, $p < .01$, $\eta^2 = .32$, compared to an ungrouped pace, and from presenting items in a semantically related arrangement, $F(1, 28) = 30.00$, $p < .01$, $\eta^2 = .52$, compared to an unrelated arrangement. Recall was also significantly better when presenting items in a visual and verbal format, $F(1, 28) = 20.64$, $p < .01$, $\eta^2 = .42$, compared to a verbal

only format. There was a significant interaction of population x semantic relation, $F(1, 28) = 8.58, p = .01, \eta^2 = .24$, whereby the effect of semantic relation was substantially larger in the TD group, $F(1, 14) = 21.14, p < .01, \eta^2 = .60$, compared to that observed in the DS group, $F(1, 14) = 9.87, p = .01, \eta^2 = .41$. There was also a significant interaction of population x grouping x presentation format, $F(1, 28) = 8.47, p = .01, \eta^2 = .23$. A further break down of this interaction revealed that while there was no significant interaction of grouping x presentation format in the TD group, $F(1, 14) = 2.83, p = .12, \eta^2 = .17$, with significant effects of grouping for both presentation formats, there was a significant interaction of grouping x presentation format in the DS group, $F(1, 14) = 7.07, p = .02, \eta^2 = .34$, (see Figure 2). In the DS group, the effect of grouping was not significant for the verbal presentation format, $t < .01, p > .99$, however the effect of grouping was significant for the verbal and visual combined presentation format, $t = 3.44, p < .01$. No remaining interactions reached significance; (highest F value = 2.41, lowest p value = .13).

Discussion

This first experiment explored the effect of manipulating temporal grouping and semantic relations in a set of memoranda upon subsequent recall performance in individuals with DS, compared to a matched TD group. The effects of these factors were compared for items presented verbally, and for these same items presented with the addition of visual information (images). The aims of the study were to a.) discover whether individuals with DS benefit from the effects of temporal grouping, semantic relations and visual presentation, simply as a result of manipulating presentation arrangement and format, and b.) determine the extent to which these effects were comparable to those seen in a matched TD group. Potential influences of presentation format and arrangement such as these are relevant to learning environments. Either the absence of an effect or differential effects in the DS group compared to the TD group would highlight differential encoding/retrieval of temporal structure in STM,

a differential influence of LTM item relation knowledge, or different strategic recall based on item relations, any of which may aid the understanding of the specific verbal STM deficit seen in this population.

The analysis revealed a significant main effect of population, whereby overall recall performance was significantly poorer in the DS group than in the matched TD group, further supporting the notion of a specific verbal STM deficit in those with DS. The main effect of presentation format (verbal only vs. verbal and visual) was significant across populations, such that individuals displayed superior memory recall when items were presented with a picture along with the verbal label compared to when presented with only a verbal label. This supports previous research suggesting that cognitive load is decreased when items are presented visually, as well as individuals benefitting from having both a verbal and a visual code for the items (Klingner, Tversky, & Hanrahan, 2011). The possibility should be acknowledged that participants may have performed better in the visual presentation condition due to increased practice, nevertheless, of main interest regarding the presentation manipulation was how presentation format interacted with the other manipulations, i.e., grouping/semantic relation, as discussed further on, as well as population. The overall benefit of visual presentation was no larger in the DS group than the TD group. Thus individuals with DS do not appear to be more reliant on visual processing than mental age matched groups, they are simply experiencing specific verbal STM problems while visual STM performance is in line with that observed in matched controls (Jarrold & Baddeley, 1997). This is consistent with the findings of Jarrold, Baddeley, and Phillips (2002) who also found broadly comparable visual benefits in a DS group compared to a TD group. It is also in line with the findings of Laws (2002), who also showed no visual memory *advantage* for a DS group compared to a TD matched control group in a colour memory task.

The effect of temporal grouping was significant, whereby overall recall was superior for items presented in a temporally grouped schedule, compared to an ungrouped schedule, across both populations. This suggests that both populations find it easier to recall items when they are presented with a temporally grouped structure at input. The hierarchical structure thought to be provided by temporal grouping (Burgess & Hitch, 1992; Farrell, 2012; Wickelgren, 1967), may therefore be allowing participants to encode and retrieve items based on the separate sub-sequences defined by the temporal context. According to Farrell's (2012) model, each cluster (in the case of the current study, each pair) is organised much like the way one distinguishes separate episodes in episodic memory. The temporal grouping benefit in the TD group is in line with previous research showing that TD individuals benefit from various forms of perceptual grouping at presentation (Bower & Winzenz, 1969; Frankish, 1995; Maybery, et al., 2002; Ryan, 1969). Importantly this study extends this previous work by showing that presenting items in a temporally grouped format can be beneficial for those with DS. Given research suggesting that strategic grouping abilities do not develop until around the ages of 8 to 9 (Towse et al., 1999), it may be particularly useful to present memoranda in readily grouped and organised formats in educational settings to provide a hierarchical structure for the input, particularly for those who would otherwise not yet use their own spontaneous grouping strategies.

However, there was also a significant interaction of grouping x presentation format x population, indicating differential influences of these manipulations of the input across the two populations. A breakdown of this 3-way interaction revealed that the TD group experienced a benefit of grouping during both the verbal only presentation condition and the verbal and visual combined presentation condition (see Figure 2). However, in contrast, while the DS group experienced a grouping benefit in the verbal and visual combined condition, they did not experience this grouping benefit in the verbal only condition. This has important

implications, indicating either less attention to, or poorer encoding/retrieval of the temporal structure of verbal input in those with DS. This finding would predict that difficulties in remembering the *order* of verbal items in verbal STM tasks would be seen in individuals with DS, which has been observed accordingly in other literature (Brock & Jarrold, 2005). Based on fMRI findings, Kalm, Davis, and Norris (2012) suggest that those brain areas involved in encoding group structure are more active when the input exceeds memory span; they state that the increased brain activation may indicate that encoding group structure is more demanding when memory capacity is substantially exceeded. Attending to and encoding the grouped format of verbal items may be particularly challenging for individuals with DS, due to their already reduced verbal STM capacity. High processing demands for verbally presented memoranda and possibly a lack of attentional resources in those with DS could therefore underlie the lack of verbal grouping effect, and a difficulty in encoding or attending to the temporal organisation of input is likely to further compound their performance difficulties. In contrast, the finding that pictures were necessary for any grouped presentation effect to be observed in the DS group indicates that those with DS are capable of encoding the temporal structure of input when there is a visual component to the memoranda. A larger visual STM capacity (in comparison to verbal STM) in the short-term domain for individuals with DS may provide them the additional attentional resources required to attend to the structured format of the incoming input, encoding and subsequently retrieving items according to this structure. If those with DS are remembering the items according to visual mechanisms, it is possible that the temporal grouping results in interactive imagery for the two items grouped together, with two items of a given pair of pictures imagined interacting together (see above, cf. Bower, 1970).

Having said this, if interactive imagery were playing a role, then one would also expect to observe certain interactions involving semantic relation, since semantically related

items, such as dog and bone are likely to result in interactive imagery much more easily than unrelated items, should one be using such a technique. As a result of interactive imagery one might expect to see three effects; first an interaction of semantic relation x presentation condition, whereby semantically related pairs are easier to recall in the visual and verbal combined presentation condition compared to verbal only, due to the visual presentation component encouraging visual interactive imagery of pairs. Second, one might expect to observe a 3 way interaction of semantic relation x grouping x presentation, with a greater benefit of semantic relations between temporally grouped pairs, compared to ungrouped pairs, during verbal and visual presentation as opposed to verbal-only presentation, as this would indicate that interactive imagery of grouped items (enhanced by semantic relations) results in the grouping effect during visual presentation. In other words, if grouping benefits during visual presentation reflect interactive imagery, then the grouping benefit should be more pronounced for related items such as dog and bone than for unrelated items such as dog and umbrella. Finally, given that the grouping benefit in the visual plus verbal condition in contrast to the lack of grouping effect in the verbal only condition was specific to the Down syndrome group, one would expect to observe different interactions for the two populations. For example, a 4 way interaction of population x grouping x semantic relation x presentation format, or a 3 way interaction of population x semantic relation x presentation, would be expected, whereby population differences would be observed regarding the interactions of these remaining variables (semantic relation, grouping and presentation format). In fact, no such interactions were significant; this suggests that an interactive imagery approach does not drive the specific grouping benefit during verbal plus visual presentation for the DS group.

Turning to an alternative possibility, previous researchers have observed recall benefits as a result of manipulating spatial location of items to produce spatially differentiated groups (Anderson & Matessa, 1997; Parmentier & Maybery, 2008). The benefit

of temporal grouping during verbal plus visual presentation experienced by those with DS may involve spatially differentiating the visual items when they are presented within a temporally grouped schedule, but not necessarily with the two items in the form of an *interaction*. Parmentier, et al. (2006), explored the effect of temporal grouping upon typically developing adult participants' visuospatial serial recall performance, and found that temporally grouped presentation alone (Exp 4) was sufficient to result in memory recall benefits in the visual domain. Specifically, the migration of visuospatial items between groups at recall was decreased as a result of temporal grouping. Parmentier et al., (2006) concluded, 'Temporal grouping can be used to induce a hierarchical organisation of the visuospatial sequences' (pp. 211-212). Thus, there appears to be a visual clustering mechanism driven by proximity, either directly as a result of spatial proximity of visually presented items, but also as a result of temporal proximity, whereby it appears that temporal proximity can also be mentally represented by spatial proximity of the visual items during visuospatial STM tasks.

The main effect of semantic relation on performance was also significant, such that items presented in a semantically related arrangement were recalled significantly better than these same items when presented in an unrelated arrangement. This effect of semantic relation was observed across both populations but to different extents, as demonstrated by the significant interaction of semantic relation and population. The pattern was such that the benefit of the semantically related arrangement of items was smaller in the DS group compared to the TD group. This suggests that individuals with DS are not using the relatedness between the items as a cue to recall memoranda, or as an organisational strategy, to the same degree as those without DS. According to Bjorklund (1987), individuals' knowledge base can impact on their memory recall performance in three ways; these are, by increasing the accessibility of items, by facilitating the use of strategies and by activating

relations between items. Importantly, Bjorklund noted that semantic relations among items are activated with very little effort. Given that the two populations were matched for vocabulary knowledge, they would be expected to have relatively similar knowledge of the words that served as the memoranda in this study. The findings from the current study suggest that despite a similar knowledge base, there is however a reduced influence of LTM knowledge of item relations in those with DS, this is likely to contribute to poorer verbal STM performance in these individuals. The effect of semantic relation did not interact reliably with presentation condition (verbal vs. verbal and visual), and the 3-way interaction between population, semantic relation, and presentation format was similarly non-significant, indicating that individuals in both groups were not using a predominantly visual strategy such as interactive imagery (Bower, 1970) to recall items presented in a semantically related arrangement. Thus, although those with DS appear to rely on a visual mechanism with regards to grouping benefits, it appears that LTM verbal associations underlie the benefit of semantically related items. The significant semantic relation effect that was observed in the DS group (as well as the TD group) may reflect the type of automatic influence of semantic knowledge upon STM highlighted by Bjorklund, with this influence appearing to be smaller in the DS group than that experienced by TD individuals.

This reduced LTM knowledge influence in the DS group compared to the TD group appears inconsistent with previous findings such as Brock and Jarrold (2004), who showed large benefits of LTM lexical knowledge in DS upon STM performance, (with no significant difference between the degree of lexicality effect upon those with DS compared to a matched TD group), however, it is likely that the difference in these results is driven by the difference in manipulation. Whereas those with DS experience a large benefit for recalling words relative to their extreme difficulty recalling nonwords, i.e., items with no LTM trace vs items with an existing LTM trace, in contrast, in the current study the benefit involves the

activation of items via relations. Thus, it appears that while those with DS are clearly influenced by LTM knowledge (note: the effect of semantic relation did reach significance in the DS group in the current study), the degree of activation of relations among items may be reduced in those with DS. Alternatively participants' ability to subsequently retrieve items based on recalling these relations may be less efficient in those with DS.

To summarize, Experiment 1 revealed that individuals with DS do benefit from grouping, semantic relation, and visual presentation. However, in comparison to a TD group some key differences were highlighted. These differences, namely an absent benefit of grouping during verbal presentation and a smaller overall benefit of semantic relation in the DS group compared to the TD group could, however, be a consequence of the clearly significantly poorer overall level of performance of the DS group than the TD group. The impact of poorer overall performance in the DS population on the extent to which these experimental manipulations affect recall is important to consider, as the effects of any manipulation could simply be proportional to baseline levels of performance (cf. Jarrold & Citroën, 2013). If so, then substantially lower overall recall abilities in the DS group would lead to apparently smaller effects of the various manipulations in this population than in the TD group, and in general any experimentally induced effects would be expected to be attenuated when performance nears floor levels. A follow up Experiment (Exp 2) was therefore carried out, with the aim of enhancing baseline performance in the DS group and determining whether the same pattern of findings was still observed.

Experiment 2

Experiment 2 was a follow up study. Only the DS group was retested, and trial list size was reduced from 6 items to 4 items with the intention of enhancing performance so that this group's baseline performance was more closely aligned to that of the TD matched group from

the original experiment. All remaining aspects of the experiment were identical. Hence, Experiment 2 aimed to reveal whether the effects of semantic relation, temporal grouping and presentation format on those with DS matched those seen in Experiment 1 when this group's baseline level of performance was more comparable to that of the TD group in the first Experiment.

Method

Participants

The same 15 individuals with DS (mean age = 20y, 5m, $SD = 7y, 6m$, range: 10y, 5m -29y, 11m) who participated in Experiment 1 took part in the follow up Experiment, approximately 2 months after having taken part in Experiment 1.

Design

The design was identical to that of Experiment 1.

Procedure

The procedure was identical to Experiment 1, other than the participants receiving 4 instead of 6 items on a trial. For each trial the last pair in the list was removed, the arrangement of the remaining 4 items in the related arrangement and in the unrelated arrangement is shown in Figure 3.

Results

A $2 \times 2 \times 2 \times 2$ Anova was again carried out, identical in form to that conducted in Experiment 1, that retained the TD data from Experiment 1 but with the retest data replacing the original data for the DS group. Corresponding descriptive statistics for the retest data for individuals with DS, are displayed in Table 2.

The between subjects effect of population verged on significance, $F(1, 28) = 4.31, p = .05, \eta^2 = .13$, such that the DS group still performed less well overall than the TD group. However, overall levels of performance in the two populations were considerably closer to each other than was observed in the original data. Again, there were significant within subjects effects of grouping, $F(1, 28) = 12.44, p < .01, \eta^2 = .31$, of semantic relation, $F(1, 28) = 23.28, p < .01, \eta^2 = .45$, and of presentation format, $F(1, 28) = 27.87, p < .01, \eta^2 = .50$, all in the same direction as observed in the original data. The interaction of population x semantic relation was now just nearing significance, $F(1, 28) = 3.73, p = .06, \eta^2 = .12$, such that the DS group again experienced a smaller semantic relation benefit, $F(1, 14) = 4.55, p = .05, \eta^2 = .25$ than that observed in the TD group (see original analysis).

The interaction of population x grouping x presentation format was again significant, $F(1, 28) = 7.67, p = .01, \eta^2 = .24$. A breakdown of this interaction revealed the same patterns as observed in the original data. While there was no significant interaction of grouping x presentation format in the TD group (see original analysis), this interaction was again significant in the DS group, $F(1, 14) = 4.92, p = .04, \eta^2 = .26$. This interaction for the DS group again reflected a significant effect of grouping during verbal and visual combined presentation, $t = -3.17, p = .01$, in contrast to no significant effect of grouping during the verbal only presentation condition, $t = 0.47, p = .65$.

All remaining interactions were non-significant, as was the case in the original data. It should be noted that the interaction of presentation format x semantic relation, $F(1, 28) = 3.62, p = .07, \eta^2 = .11$, had a relatively low, though non-significant p value, with a larger benefit of semantic relation in the verbal and visual combined as opposed to the verbal only presentation condition. For the remaining interactions the highest F value = 1.71, the lowest p value = .20.

Discussion

In this follow up experiment, in which the DS group repeated the experiment with 4 instead of 6 items per trial, performance improved in this group as would be expected. Even under these testing conditions the DS group still showed poorer overall recall at retest compared to the TD group (from Experiment 1), however, this difference just neared significance. As a result, compared to the original comparison of groups, baseline levels were much less discrepant across the two populations when the DS retest data were employed. Importantly, for both the original analysis and for the analysis with DS retest data, the same patterns of effects were observed.

The main effects of grouping, semantic relation and presentation format were all significant in the follow up experiment, reflecting the same benefits as observed in the original analysis. These were, specifically, a benefit of presenting items at a temporally grouped pace compared to an ungrouped pace, a benefit of presenting items in a semantically related arrangement compared to an unrelated arrangement, and a benefit of presenting pictures with the verbal labels, compared to only verbal labels. More importantly, the reliable interactions involving population remained in the follow up comparison, indicating that these interactions did not simply result from proportional scaling effects due to markedly lower baseline performance in those with DS in Experiment 1. The 3-way interaction of grouping x presentation format x population remained significant, with the DS group only benefitting from temporal grouping of input when there was a visual component at presentation. In contrast, there was again no grouping effect for those with DS when memoranda were presented verbally only. One possibility touched upon in the discussion of Experiment 1 was the idea that individuals with DS may have difficulty encoding grouped structure during verbal presentation due to a reduced verbal memory capacity affecting their processing ability, (Kalm, et al., 2011), however, it is worth noting that the effect size for this 3-way

interaction was very similar in Experiments 1 and 2, $\eta p^2 = .24$ and $\eta p^2 = .23$ respectively. Thus, reducing memory load did not appear to influence size of this effect, indicating either, a.) that 4 items is still sufficiently above capacity, such that individuals with DS find it too difficult to attend to/encode and retain the grouped arrangement of verbal items, or b.) regardless of capacity, a fundamental difference in the processing of the temporal structure of verbal input is at play here. In the retest experiment the absent grouping benefit during verbal only presentation was again in contrast to a significant effect of grouping when a visual component was introduced. Hence, this finding in the retest data strengthens the argument that individuals with DS benefit from a visually-based grouping mechanism, such as spatially clustering the two pictures of a group/pair.

The semantic relation x population interaction was nearing significance in the retest data, ($p = .06$). This finding again indicates that individuals with DS may not be experiencing semantic association benefits to the same extent as the matched TD group, reflecting either less automatic influence of LTM knowledge, or possibly less active strategic use of LTM knowledge. We should further note that despite the DS group experiencing less semantic relation benefit than the matched TD group, the semantic relation benefit they experienced did still verge on significance in the retest data, ($p = .05$).

General Discussion

The findings from the current study highlight some key similarities as well as some key differences between a group of individuals with DS and a matched TD group as they perform verbal STM tasks. The findings revealed that individuals with and without DS experienced benefits recalling items in the correct pair position as a result of temporal grouping, as a result of semantic relations, and as a result of pictures accompanying the verbal labels of items at presentation. However, this study again showed the reliable overall

finding that verbal STM is severely limited in individuals with DS relative to matched TD children, and interactions involving population with semantic relation, as well as population with temporal grouping and presentation format highlighted differences between the populations in the mechanisms underlying these effects.

The overall finding of a temporal grouping benefit aligns with numerous previous studies whereby grouping of the input at presentation has been shown to provide a recall benefit, (Bower & Winzenz, 1969; Frankish, 1995; Maybery, et al., 2002; Melkman, et al., 1981; Ryan, 1969). Given that young children and those with DS may not have the ability to use spontaneous grouping strategies (Towse, et al., 1999), it would be particularly useful to provide structure at input for young children and those with DS as well as perhaps for other learning disability groups, to enhance their performance during STM tasks. However, a key difference between the two populations regarding the effect of grouping was also found in this study, whereby those with DS only experienced the grouping benefit for items presented with a visual component, in contrast to the TD group who experienced a grouping benefit in both presentation conditions. This is an important finding as temporal grouping provides individuals with an extremely useful tool to reduce memory load during verbal STM tasks. According to Farrell (2012) verbal input is encoded according to the temporal context, whereby input is organised hierarchically. If individuals with DS struggle to attend to or encode the temporal context of incoming verbal only memoranda then they will have difficulties with organised retrieval of items and problems remembering the serial positions of items. Additionally, given that individuals with DS appear to have a smaller verbal STM capacity than comparison individuals (Purser & Jarrold, 2005), they are likely to experience poorer item memory along with difficulties recalling order information. Such a pattern, whereby individuals with DS are less able to recall items as well as being less able to recall the serial positions of the items that they do recall, compared to matched TD groups, is

consistent with previous studies. Individuals with DS have displayed order memory problems in previous research, (Brock & Jarrold, 2005), along with other studies also observing item memory difficulties (Brock & Jarrold, 2004; Marcell, Harvey, & Cothran, 1988). A lack of temporally structured organisation for verbally presented memoranda may therefore contribute substantially to the specifically poorer verbal STM performance in comparison to significantly better visual STM performance in individuals with DS (Brock & Jarrold, 2005; Jarrold, et al., 2000; Vicari, et al., 2004).

On the other hand, the finding of a temporal grouping benefit in those with DS when pictures were included at presentation, compared to their lack of temporal grouping benefit during verbal only presentation, indicates the importance of visual information for those with DS. The grouping benefit observed in the DS group during visual and verbal combined presentation did not appear to be due to interactive imagery of the grouped images, since one would have expected to also see a significantly larger semantic relation benefit during visual presentation compared to verbal only presentation if this were the case, or an interaction of semantic relation x grouping during verbal and visual presentation in contrast to no significant interaction during verbal only presentation for the DS group; neither pattern was observed in the data. Assuming then, that the grouping benefit specific to the visual presentation condition in the DS group is at least not predominantly based on interactive imagery, the benefit may instead take the form of spatially organising the pictures in their separate pairs. Participants may be internally representing temporal proximity as spatial proximity, (Boroditsky, 2000). This finding is consistent with those of Parmentier et al. (2006) who also reported hierarchical organisation of visuospatial items as a result of temporal grouping at presentation.

The findings from this study additionally showed that individuals with DS do benefit from semantic associations, recalling more items when these items were organised into

semantically related pairs. Other aspects of the results suggest that this benefit was verbally based for both populations, rather than being predominantly visually based due to the use of imagery. In line with previous research, this supports the notion that existing verbal LTM knowledge can have a top-down influence upon verbal STM in those with DS (Brock & Jarrold, 2004; Raitano Lee, Pennington, & Keenan, 2010), as well as being consistent with previous evidence that those with DS do organise semantic items in a similar nature to those without DS (Nash & Snowling, 2008). Bjorklund (1987) suggested that once semantic knowledge is obtained it can influence STM recall quite effortlessly. While the DS group did experience a significant benefit of semantic relation in the current study (this effect was significant in the original comparison, and just nearing significance for the retest data, $p = .05$), they nevertheless displayed less benefit from the semantically related arrangement of items than did the TD group, even though the two groups were well matched for vocabulary knowledge. Given that the interaction between population and semantic relation only neared significance in the follow up experiment, it can only be interpreted tentatively. However, it implies that item relations in LTM are not activated as strongly in the DS group compared to the TD group during STM tasks. It is also possible that at retrieval participants are less efficient at moving between pairs of related items. For instance, and in line with the conclusions of Nash and Snowling (2008), those with DS may also have poorer retrieval strategies, whereby they find it more difficult than matched TD controls to move between semantically organised clusters at recall. This may also align with the findings of Carlesimo, Marotta, and Vicari, (1997) who reported less efficient use of category knowledge in those with DS.

These observed patterns of similarities and differences in the two populations therefore inform our understanding of the nature of verbal STM difficulties in DS and thus have implications for the design of any future interventions. Specifically, the findings

highlight two potential routes for intervention with this population, first training individuals to increase their use of compensatory visual strategies, and, second, directly attempting to enhance the specifically poorer verbal STM encoding and retrieval. With regards to visual strategies, the findings from this study, along with previous research (Jarrold et al., 2002; Laws, 2002), indicate that those with DS are not experiencing any larger benefit when input is visual than that observed in matched TD control groups. However, given that individuals with DS have a much less limited visual than verbal STM capacity, it may be that visual compensatory mechanisms or strategies, developed via instructional training, would offer potential for improvements in memory performance. This study also highlights the fact that visual presentation formats are compatible with other organisational presentation techniques, such as grouping, for use with those with DS; this could be capitalized on in educational settings. This is important to consider given that the temporal grouping benefit observed during verbal plus visual presentation was absent in the verbal only condition. Thus highlighting that the structure provided at input needs to be compatible with presentation format for memory recall benefits to be experienced, and this format is dependent on individual differences.

Alternatively, with regards to the verbal domain, it is clear from both experiments that at least two processes are less efficiently used to support memory performance in individuals with DS than would otherwise be expected. The first of these is the encoding or retrieval of the temporal context of verbal input in the STM domain. The second is the influence of, or strategic use of, verbal LTM knowledge to support STM recall. Presenting verbal only memoranda in a grouped schedule compared to an ungrouped schedule did enhance performance in the TD comparison group, and the TD group also experienced a larger benefit than the DS group from items being presented in a semantically related as opposed to unrelated arrangement. Individuals with DS could therefore benefit from meta-awareness of

the relations between items, and instructions to think about how words relate, along with prompts to train individuals to recall items based on associations, e.g., if the participant recalls one item (boat) they could be prompted to recall the associated item, such as ‘where was the boat?’ to cue the associated item ‘sea’. Likewise, individuals with DS could benefit from training in techniques to enhance encoding or retrieval of the temporal context and structure of verbal information, possibly through techniques focussing attention on the rhythm of the phonological input, phonological awareness, or meta-memory techniques, (Pressley, Borkowski, & O’Sullivan, 1984; Schneider, Bjorklund, Valsiner, & Connolly, 2003). Finally, it is also clearly important for educators to be aware of the underlying memory capacities of groups of individuals such as those with DS. Without this knowledge there is a danger that the amount of information presented to individuals would be at an inappropriate level, and the associated processing demands would be too high to allow individuals to use these strategies to improve their performance during verbal STM tasks.

In conclusion, this study has shown that without any instruction, grouping benefits can be induced in the DS population, as well as in young children, simply as a result of the input being presented in separate groups that provide temporal structure. Presenting information in a structured, organised format is therefore a useful approach if one is seeking to maximise immediate recall. However, this study also highlights the importance of presentation format. In particular, we have shown that visual support may be crucial in order for individuals with DS to experience certain organisational effects. The use of visual strategies to further compensate for their verbal STM difficulties could be encouraged for those with DS. This study has additionally shown that individuals with DS do experience benefits from their existing verbal LTM knowledge regarding the memoranda. In particular this study shows that there may also be room for improvement regarding the use of LTM knowledge to support verbal STM recall for those with DS, since those with DS did not

experience semantic relation benefits to the same degree as TD matched peers in this study, despite matched vocabulary knowledge. Individuals with DS could be taught to attend to relations between items to allow for a greater influence of LTM upon verbal STM. Finally, the DS participants assessed here displayed poor encoding of temporal context for verbal only input. Given that these individuals may well have a limited verbal STM capacity, it is crucial that they can encode any input within that capacity to their maximum potential. This requires efficient attention to and encoding of the temporal context of the input. Intervention is clearly needed to address these issues, with the types of training approaches discussed above. A balance of relevant training in verbal and visual techniques, as well as presenting information in formats that play to individuals' strengths (e.g., providing structure and visual support), is therefore required in educational settings, to allow individuals to perform to their maximum potential.

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Table 1. Means and standard deviations for semantically related and non-semantically arranged items, when grouped and when not grouped, in both the verbal only condition and the verbal and visual presentation condition for each population (TD and DS).

	DS (<i>M, SD</i>)	TD (<i>M, SD</i>)	Grand Mean
Verbal Only:			
Ungrouped:			
Non-Related	2.13 (2.23)	8.00 (6.27)	5.07
Related	3.13 (2.20)	11.73 (7.04)	7.43
Grouped:			
Non-Related	2.00 (1.73)	11.73 (7.62)	6.87
Related	3.27 (2.89)	14.33 (8.83)	8.80
Grand Mean:	2.63	11.45	
Verbal & Visual:			
Ungrouped:			
Non-Related	2.33 (1.95)	11.00 (7.71)	6.67
Related	3.53 (2.90)	16.20 (10.13)	9.87
Grouped:			
Non-Related	4.47 (3.04)	12.93 (8.76)	8.70
Related	5.67 (4.43)	16.80 (9.56)	11.29
Grand Mean:	4.00	14.26	

Table 2. Means and standard deviations for semantically related and non-semantically arranged items, when grouped and when not grouped, in both the verbal only condition and the verbal and visual combined condition for individuals with DS.

DS	
<i>M (SD)</i>	
Verbal Only:	
Ungrouped:	
Non-Related	6.80 (4.04)
Related	8.47 (4.76)
Grouped:	
Non-Related	7.27 (3.65)
Related	7.33 (3.62)
Grand Mean:	7.47
Verbal & Visual:	
Ungrouped:	
Non-Related	7.53 (3.87)
Related	9.20 (5.12)
Grouped:	
Non-Related	9.13 (3.38)
Related	12.33 (5.45)
Grand Mean:	9.55

Figure 1. Item arrangements across the 4 blocks, and temporal presentation durations (milliseconds) for items when presented in the ungrouped schedule, and in the temporally grouped schedule.

Figure 2. The effect of temporal grouping upon mean memory recall performance (with standard error), during the verbal only presentation condition and during the verbal plus visual presentation condition. Left panel shows performance in the DS group. Right panel shows performance in the TD group.

Figure 3. Arrangements of the remaining 4 items of the trials across the 4 blocks in the follow up experiment.

1 **Non-related + Ungrouped:** boat / dog / table / sea / bone / chair

2. **Related + Ungrouped:** chair / table / bone / dog / sea / boat

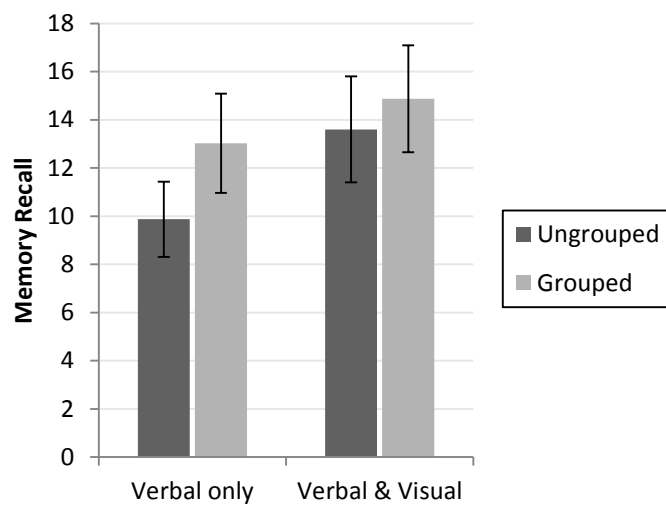
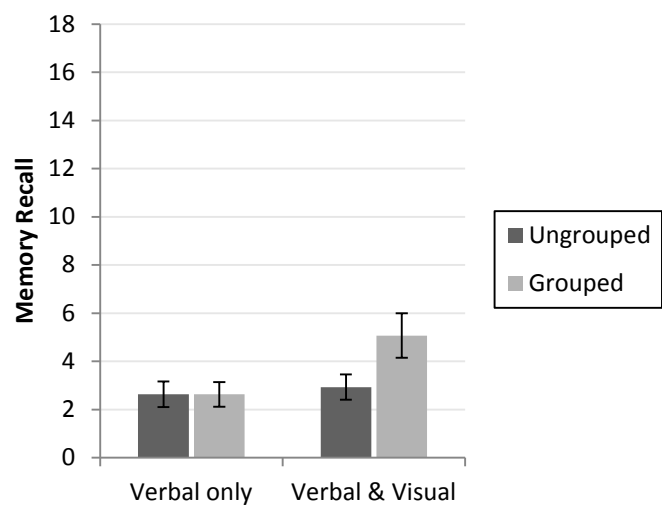
3. **Non-related + Grouped:** bone/sea / chair/dog / boat/table

4. **Related + Grouped:** dog/bone / boat/sea / table/chair

/ = 100 ms

/ = 1100 ms

/ = 600 ms



1. **Non-related + Ungrouped:** dog / table / bone / chair

2. **Related + Ungrouped:** chair / table / bone / dog

3. **Non-related + Grouped:** bone/chair / dog/table

4. **Related + Grouped:** dog/bone / table/chair

/ = 100 ms

/ = 1100 ms

/ = 600 ms